[redacted] STAT

15 January 1964

OUTLINE OF REPORT

A. Objective Measures of Image Quality

1. Discussion of edge measurement techniques for determining the optical transfer function.

The aim here is to provide a reliable and reproducible "canonical" technique for accurately measuring t (k), particularly for high spatial frequencies (say 10 ft ground resolution or 100 L/mm). We want to know t (k) for two reasons. By comparing the measured t (k) with the value to which the system is designed we can hope to answer whether the photography obtained is all that we can expect from C/M or whether there is a loss of resolution due to shortcomings of the system. Since the atmosphere's transfer function enters into this comparison it too must be measured or calculated as part of a measurement program. This is discussed further in Section D. A second major reason for finding t (k) is to determine the trade offs between resolution, say in L/mm, vs film graininess, vs contrast measured by $D_{max} - D_{min}$ when it comes to optimizing a system with regard to the users' ability to gain intelligence value from the photography.

The practicability of edge measurements for a routine evaluation of photography at high resolution must still be established. Experiments are in progress, further ones are proposed, and the institution of an unclassified professional study for standardization of edges and edge scan techniques to demonstrate practicability of this method for high resolution analysis is recommended.

2. <u>Visual comparison of photography of unknown quality with photography of known quality as obtained by the same optical system.</u>

This technique of subjective quality comparators or JEMS for judging image quality is of great interest because there are no standard resolution targets in operational photography and the edge scan measurements are still of unproved practical value. Moreover comparative analysis of properly prepared JEMS may provide some valuable input into a human equation for the optimum photography for use of the intelligence community.

The first use of such photographic comparators is for engineering evaluation. They are designed to permit the observer to identify the main specific characteristics of quality degradation in the actual picture - whether due to reduction of the optical transfer function, non-optimal processing to high or low average densities, or low contrast due to haze or thin clouds - by comparison with a library series of JEMS that can be brought to adjacent positions in sequence. The second use would be to determine the effects of the variables introduced into the JEMS on the value of photographic material for intelligence purposes. To reiterate an earlier point - our primary committee concern is to determine how well the system produces its design transfer function but the question of what transfer function to which the system is to be optimally designed is a longer range and corollary question.

A comparison technique for assessing the photographic quality is presented and the basic elements of a JEM library are discussed here. As the first step in implementing this program a simple dual microscope system and a small library with JEMS of varying resolutions and contrasts has been prepared.

One specific datum to be hoped for from a comparison of visual photography with JEMS is a correlation with other subjective measures of image quality, such as the MIP ratings at NPIC and the RES measures at SPPL, and with results of standard 3-bar target measurements. We have found an apparently complete absence of correlation between MIP and RES ratings and it remains to establish what quantitative value if any can be placed on the one or the other. Presently a comparison of RES and edge scan measurements are in process at SPPL. In this connection we would like to place in proper perspective the performance curve plotted by [redacted] on Mission 9056 which has caused such very great concern and which helped stimulate the formation of this committee. In view of our present lack of any objective quantitative measure of image quality it is unknown how either to scale or normalize the MIP values with resolution in Lines/mm and therefore no conclusions based on such comparison are validly to be inferred. STAT

B. <u>Measurement Program</u>

1. <u>In-flight measurements for obtaining engineering data to check on system performance in the operational environment and to correlate with image quality.</u>

The C/M system is subjected to extensive laboratory tests on the ground in Boston, Palo Alto, and Vandenberg check its operation

STAT

both before and after thermal and pressure changes, in different gravity orientations, and after severe vibrations. These tests are designed to cover the range of parameters anticipated during launch and orbital phases and focal settings must remain within tolerance.

There is no way of knowing, however, that focal errors do not degrade actual system performance in flight. No in-flight measurement program exists for determining the temperature inhomogeneities in flight due to sun angles and camera barrel exposure to space and furthermore, there is no in-flight verification that the focal point is at the film. Remedies for these deficiencies are proposed. They require an in-flight measurement program not seriously interfering with operational activities. Furthermore, a vigorous and more thorough laboratory study with a theoretical model is encouraged to complement this program, providing more details as to where to put temperature sensors on board and pointing the way toward improved thermal control.

Another recurring plague of C/M photography is corona discharge. There are indications that if the vehicle, and hence film, were maintained at a pressure of 20μ to 100μ instead of at ambient, this condition would be controlled. Work is in progress to develop such a light weight pressure system, using perhaps freon or dry nitrogen and should be pressed with full support, and introduced along with a periodic pressure check.

STAT

Further elaborate ground tests over a broader range of parameters for checking film flatness are suggested. These should include a broad temperature range and should be designed to test vibration and post acceleration effects.

Direct tests on film properties and sensitometry are discussed in Section C.

2. Engineering passes with daylight photography of design aerial targets.

It is recommended that these be carried out with simultaneous recording of the data of the measurement program in 1 above until one is driven to the conclusion that the system is working up to its design potential. The resulting loss of operational coverage due to such a program is both insignificant and a very worthy investment.

The design of aerial targets is investigated and one new conclusion calls for a three dimensional target casting a shadow, the brightness of which provides a measure of contrast loss due to haze and of atmospheric scattering. In general the target is desired to provide not only a measure of contrast reduction due to atmospheric scattering but also the transfer function from an edge measurement. For the loss of contrast due to haze sensitometric exposures are desired - as proposed in Section C.

C. Film Processing and Sensitometry.

1. This is not the report but two questions must be discussed here.

a) How well do the mission parameters for slit width match with the processing curve for the cloud free regions?

b) Should a bigger range of slit widths be explored and is this an aircraft experiment?

2. Both as a monitor of film uniformity and to provide a quantitative measure of contrast, or modulation, reduction due to haze, sensitometric strips are desired continuously along the film. There are pros and cons as to whether these strips are best introduced pre-flight, in-flight, or post-flight, and pre-processing, but no compelling reasons for the in-flight sensitometry emerged. It is felt that sensitometer stripping should be a standard procedure.

D. Weather

1. Calculation of Weather Effects.

The transfer function of the atmosphere plays an important role in the considerations of each of the three preceding sections. For example, in designing to a transfer function there is limited value to striving for a lens transfer function which achieves a resolution substantially dulled by turbulence. Likewise if the DC haze filtering presents only objects of low contrast to the lens, it is for such images and not for high contrast ones that it is desirable to optimize the resolution.

In the analysis of a measurement program and comparison of the system performance and design quality with engineering passes over known design targets it is necessary to remove the atmospheric transfer function as known.

The effect of turbulence on the transfer function appears to be negligible on the scale of 10 ft ground resolution photography (2×10^{-5} rad angle) with a 5×10^{-3} sec integration time. However, there is appreciable contrast reduction as a DC effect of haze and this appears to be very sensitively dependent on local weather and its predictability over hostile territory is undertermined. Viewing tests in conjunction with engineering passes can be made and atmospheric contrast reduction directly measured and computed approximately for the analysis of edge traces and ground resolution with targets of known contrast.

Aerial target design is elaborated. The observed contrast reduction due to haze can be compared against the approximately calculable reduction according to the Koschmieder-Duntley theory which requires independent ground measurement of the luminance of the horizon sky in that direction from which the sun light is scattered through the same angle as when viewed from the satellite. It can also be compared with the measurable reduction by a standard airborne camera as an approximately coincident pass over target so that the effect of haze may be removed. This is important because frequent light leaks, indistinguishable from haze in reducing contrast, have plagued C/M.

A very rough calibration of the contrast reduction over hostile territory due to haze appears to be possible from correlation with atmospheric humidity which can be predicted with a measure of reliability from weather analysis. This method deserves further study and exploration. At the minimum we conclude that the atmosphere can be removed with reliability from domestic engineering passes in the analysis of the photography. Effects of filtering and color photography were not analyzed.

2. Prediction of Weather

The extent to which world-wide weather data can be integrated into the mission orbit selection to reduce the present average of roughly 50% cloud cover in the photography is explored but no conclusions reached.

E. Exotic Schemes

Double Diffraction Technique using negative as coherent source and preparing filter keys to remove aberrations.

Thin film bases to remove volume limitation on film in present missions.

Rotating prism scanner.